FOOD PRESERVATION
BY HURDLE TECHNOLOGY

Evangelos Sfakiotakis
Professor of Pomology
Aristotle University of Thessaloniki

Food preservation by hurdle technology

- Definition-the hurdle concept
- Basic aspects (hurdles in foods, homeostasis, stress reactions)

Applications of hurdle technology to microbial stability of foods

Applications of hurdle technology to quality of foods

- Potential of using the hurdle technology in the preservation of horticultural products

The hurdle concept

The spoilage of foods by pathogens is the main problem which is not under adequate control despite the preservation techniques available (refrigeration, CA/MA, MAP etc.).In fact the current consumer demand for more natural and fresh-like foods, which urges producers to use only mild preservation techniques. (e.g. refrigeration, CA, MAP, and bio-conservation). There is a strong need for new or improved mild preservation methods.

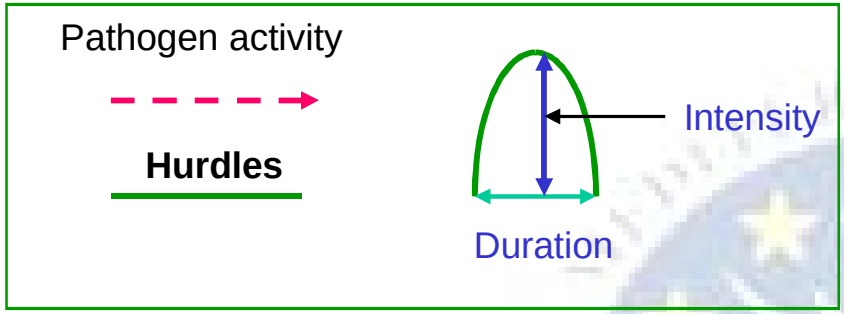
Hurdle technology (also called combined methods or barrier technology) advocates the combination of the existing and novel preservation techniques in order to establish a series of preservative factors (hurdles or barriers) that any pathogens present should not be able to overcome. The "higher the hurdle, the greater the effort.

Because of their concerted, sometimes synergistic effect, the individual hurdles may be set at lower intensities than would be required if only a single hurdle were used at the preservative technique.

The hurdle technology is used for gentle but effective preservation of foods

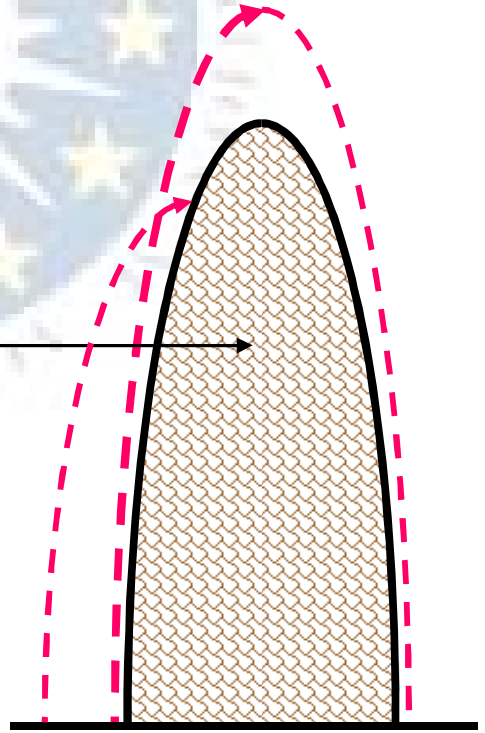
It has been suggested that it is not productive from the quality standpoint to provide extreme treatment conditions to inhibit the growth of microorganisms in refrigerated food. A suitable combinations of growth-limiting factors can be used.

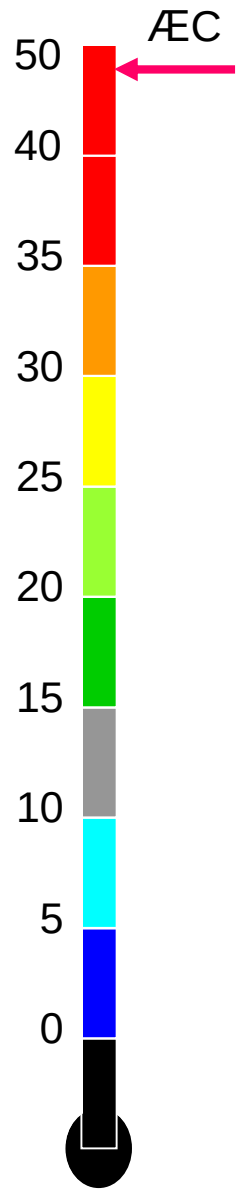
THE HURDLES CONCEPT



Pathogen (*Botrytis cinerea*)

Hurdle Intensity
(Height and exposure)
e.g. 48°C 3 min





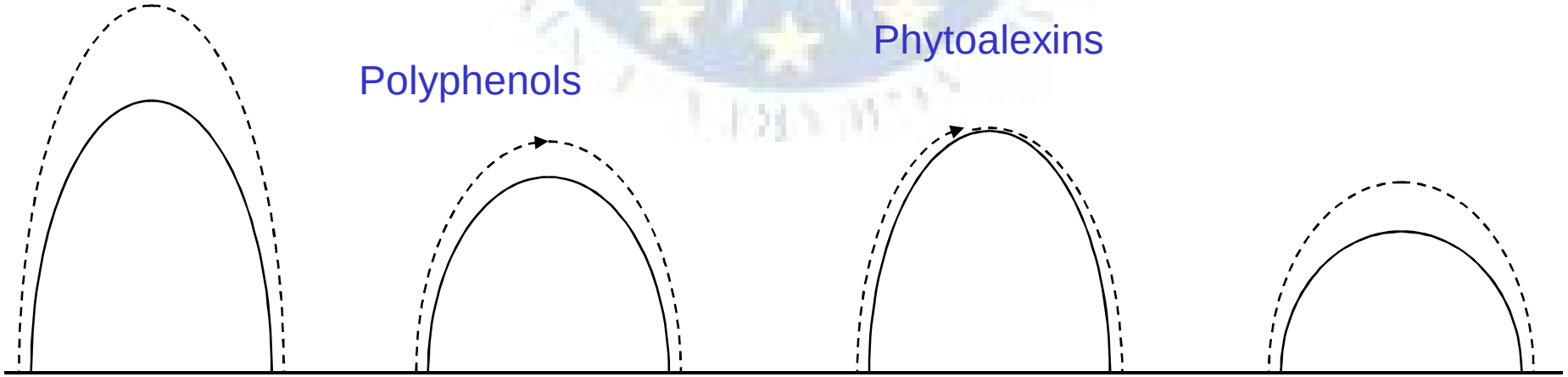
Resistance to infections
Natural barriers:

Fruit skin
(Wax)

Polyphenols

Phytoalexins

Natural volatiles



Example:

A food product is microbiologically stable and safe because of the presence of a set of hurdles that is specific for the particular product, in terms of nature and strength of these effect. Together, these hurdles keep spoilage or pathogens under control and thy can not overcome ("jump over") all these hurdles present.

Fruit in the field

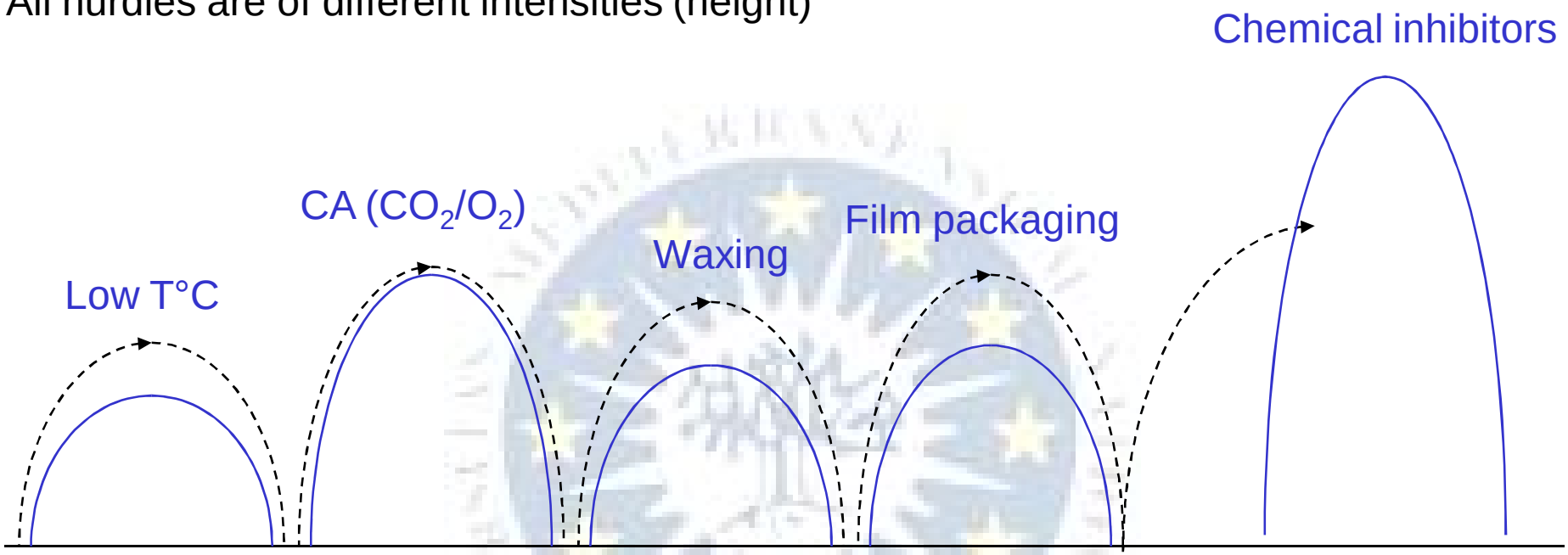
Resistance to infections

Natural barriers:

- Fruit skin (cuticle, epidermis, natural wax)
- Preformed inhibitors (phenolic compounds)
- Induced inhibitors by wounding
  - cork cells
  - phytoalexins
- Natural volatiles (essential oils)
- Competative microorganisms

Barriers during postharvest handling

All hurdles are of different intensities (height)



The individual hurdles may encountered simultaneously or sequentially, depending on the type of hurdle and the overall processing.

The Initial pathogen load is important:

If there are only a few pathogens at the start the hurdles are enough to achieve microbial stability.

If too many pathogens are present initially more hurdles (or higher intensities) are needed for microbial stability.

Hygienic conditions are important for the pathogen initial load

Fruit during postharvest handling

Resistance to infections

Natural barriers:

- Fruit skin (cuticle, epidermis, natural wax)
- Preformed inhibitors (phenolic compounds)
- Induced inhibitors by wounding
  - cork cells
  - phytoalexins
- Natural volatiles (essential oils)

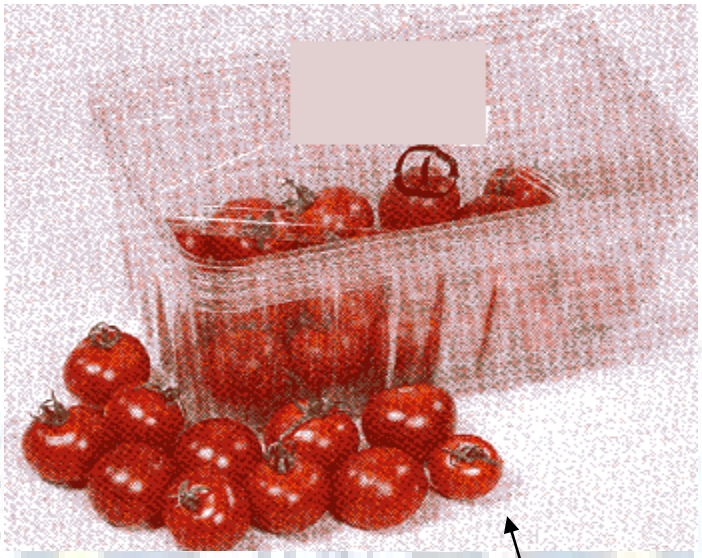
Postharvest barriers

- Low temperature in the storage
- CA (CO_2/O_2)
- Waxing (chemical)
- Film packaging
- MA
- Chemical inhibitors (pesticides)
- SO2 fumigation

Alternative barriers

- High temperature during PH handling
- Natural volatiles (AA, ethanol, essential oils etc.)
- MAP
- Edible coating
- Competative microorganisms

Barriers during postharvest handling



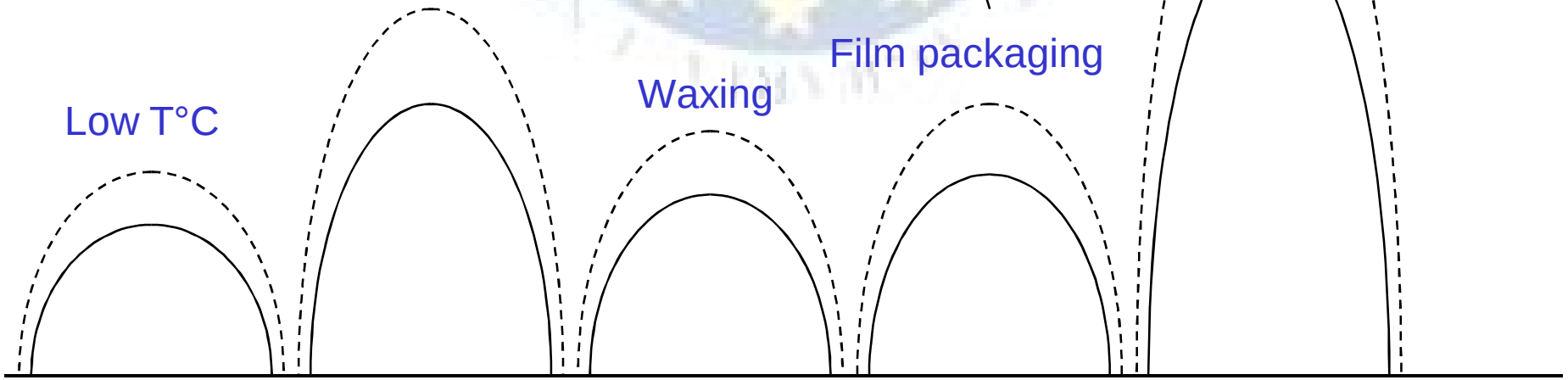
~~Chemical~~ inhibitors

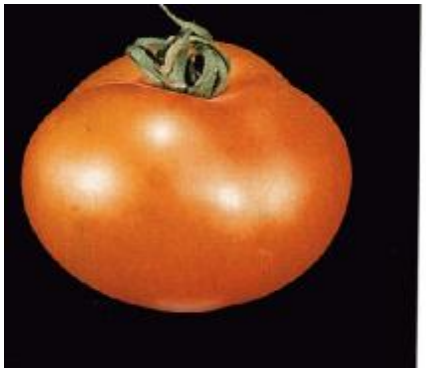
CA (high CO_2/low O_2)

Film packaging

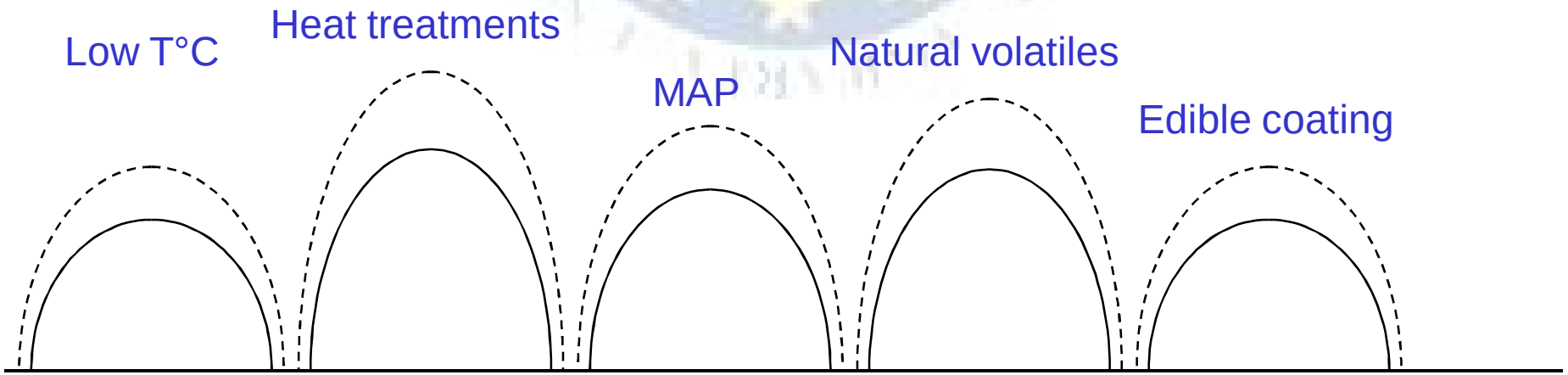
Waxing

Low T°C

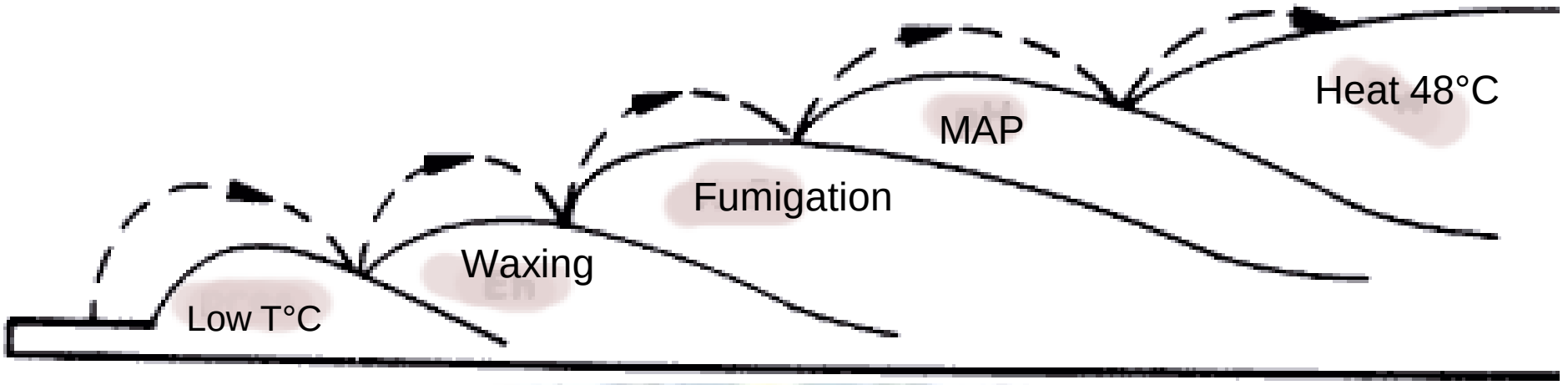




Alternative barriers during postharvest handling



Possible synergistic effects of hurdles



The individual hurdles may encountered simultaneously or sequentially

Homeostasis and hurdle technology

Homeostasis of pathogens is the tendency to uniformity or stability in the normal status (e.g. maintenance of the pH within narrow range)

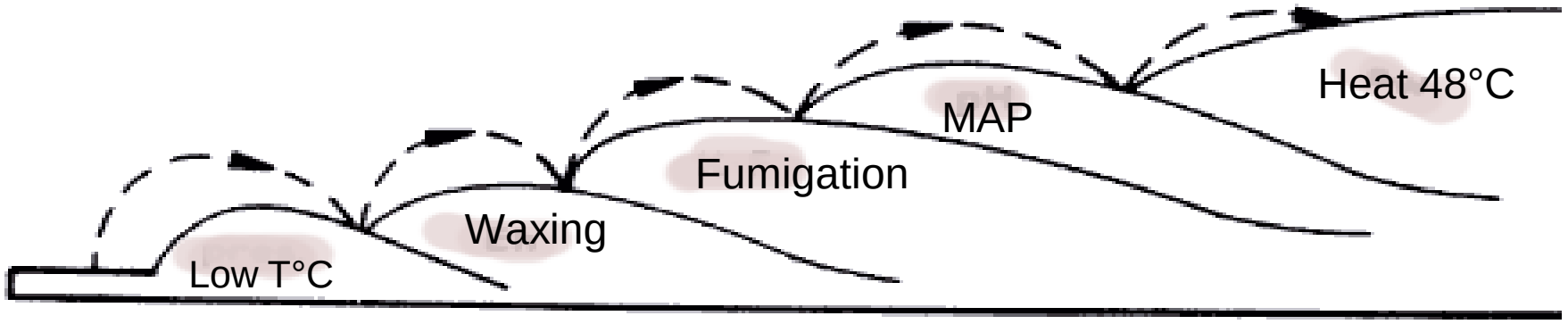
The homeostasis is disturbed by hurdles in foods, they will not multiply. They remain in the lag-phase or even die before they are repaired.

Thus food preservation is achieved by disturbing the homeostasis of the pathogens.

Multi-targeted approach is that any hurdles affect the pathogens in several different ways, e.g. affecting cell membranes, DNA, enzymes, pH etc.

This approach is often more effective than single-targeting and enables the use of hurdles of lower intensity, and thereby has less of an effect on product quality.

In practical terms it is more effective to use a combination of hurdles with low intensities affect microbial systems or act synergistically than to use a single hurdle with high intensity. The objective is to inhibit the growth than to kill it.



Stresses in the multitarget hurdle technology

Sequential or simultaneous exposure to different stresses may become the microorganisms to be exhausted. Therefore, multitarget preservation of products could be the key to differentiate the host and the pathogen reactions in favor of safety and quality preservation.

Hurdles used in the preservation (low and high T°C, fumigation, high CO2, low O2 etc.) are in fact stresses and they tends to disrupt (interrupt, restrict or accelerate) the physiological processes of a host product and pathogens in a different way.

The hurdle approach is based on the different response of product and the pathogen to the hurdle stress imposed.
The combination of different hurdles offers the potential of inducing less injury to product tissues.

Application of hurdle technology to microbial stability (food safety) and quality of food

The hurdles influence the safety as well as the quality of foods (positive or negative effects) depending on its intensity.

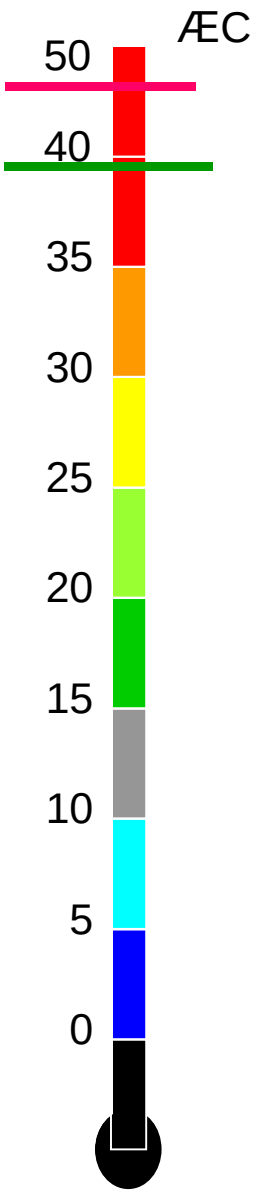
Example: Low temperature (e.g. 0°C) may improve storage quality of apples but the same hurdle (0°C) may induce chilling injury of peppers, tomatoes.

High temperature (50°C)

In order to secure the total quality of food, the safety and the quality hurdles should be kept in the optimal range.

If the intensity of a particular hurdle is too small it should be increased to secure the safety target,

If the intensity (height and exposure) is detrimental to the food quality it should be lowered



Stress reactions and hurdle technology

A stress is an external factor of such magnitude that it tends to disrupt the normal physiological processes of the organism (host product or microorganism).

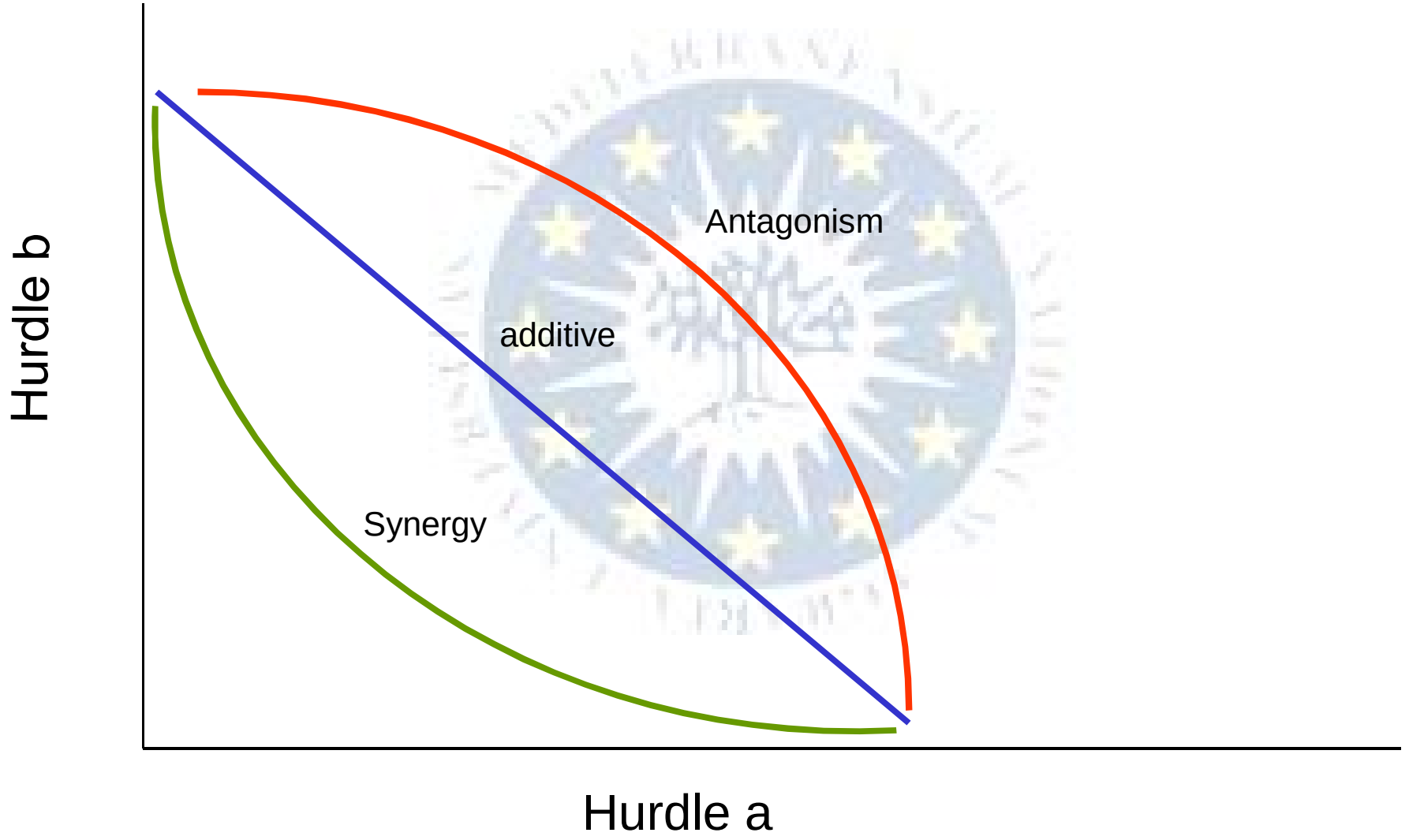
A stress, interrupts, restricts or accelerates normal metabolic processes and does so in adverse or negative manner.The extend of injury sustained is determined by the severity of injury, the length of time the organism is exposed and the organism's resistance to the stress.

Stress can produce an injurious effect (direct, indirect, or secondary stress).

The injurious effects for the pathogen come primarily from the inhibition of growth, and are less related to survival and death of microorganisms.

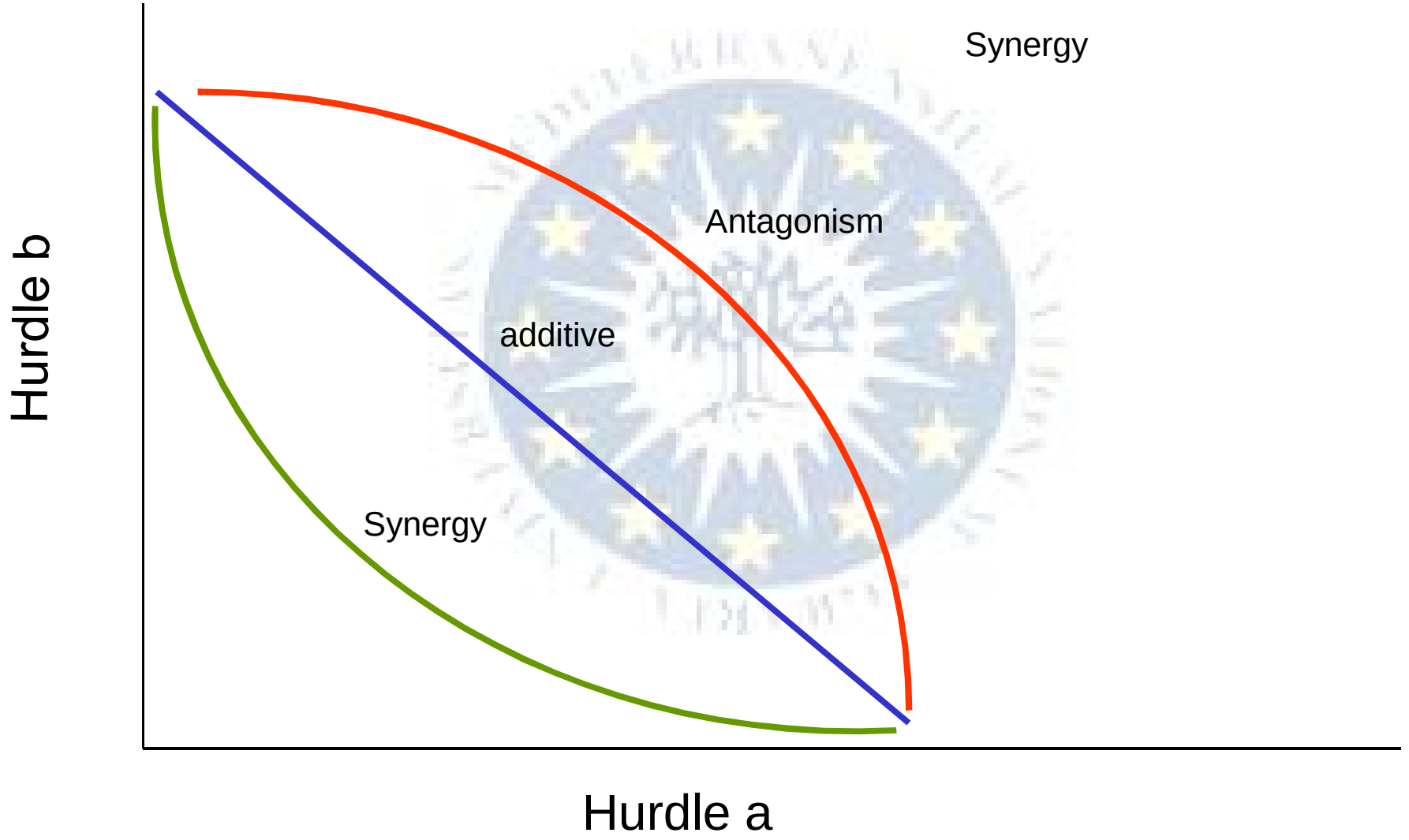
The injurious effects for the product is related with the maintenance of quality characteristics.

Synergy the interaction of two or more agents such as that the combined effect is greater than the than the expected sum of the individual effects (2X3=6)
Additive the interaction where the combined effect is exactly the sum (2+3=5)
Antagonism the interaction where the combined effect is less than the sum (2+3=<5)



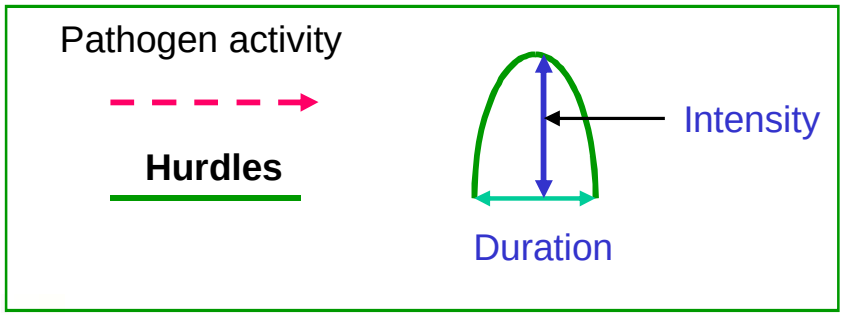
The concept of combining hurdles

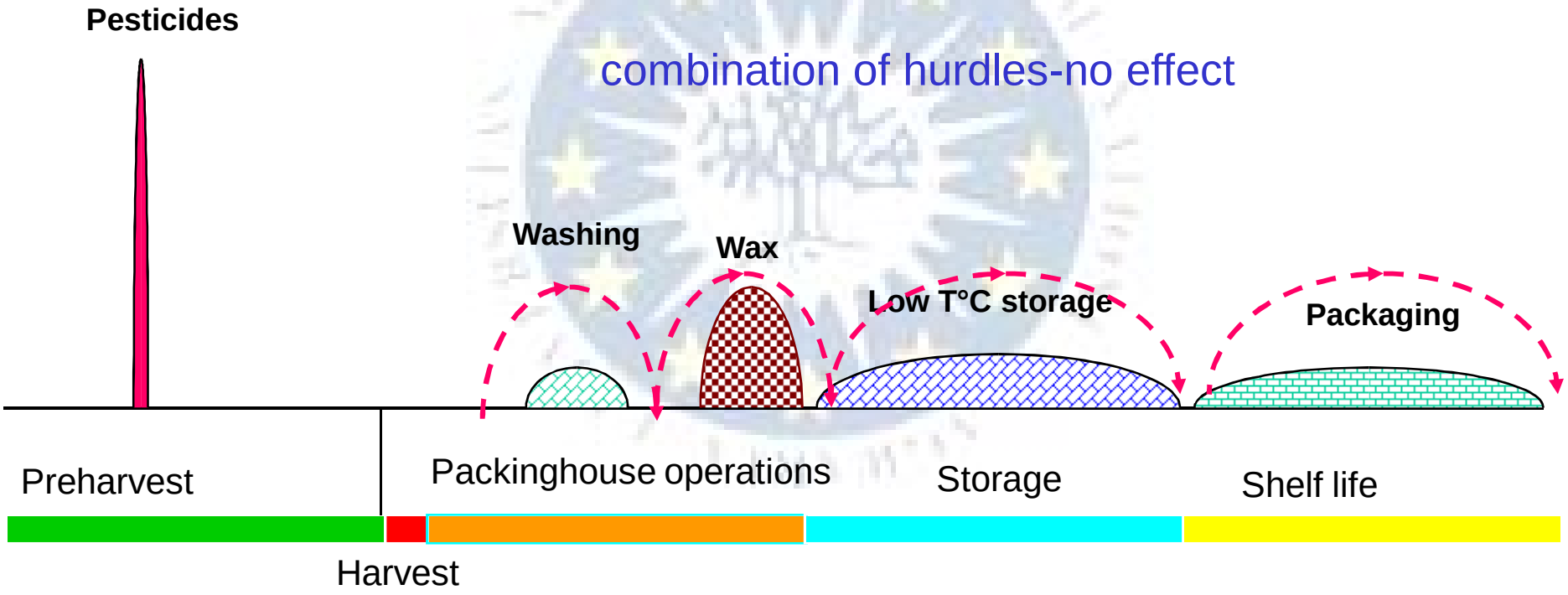
The hurdles provided must at minimum be additive in action preferably synergistic and not antagonistic



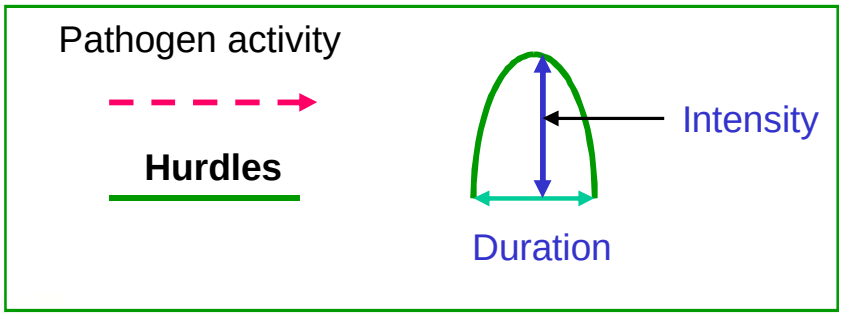
Potential of using the hurdle technology in the preservation of horticultural products

Example: The pathogen present in the packinghouse overcomes ("jump over") all the hurdles and the commodity deteriorates





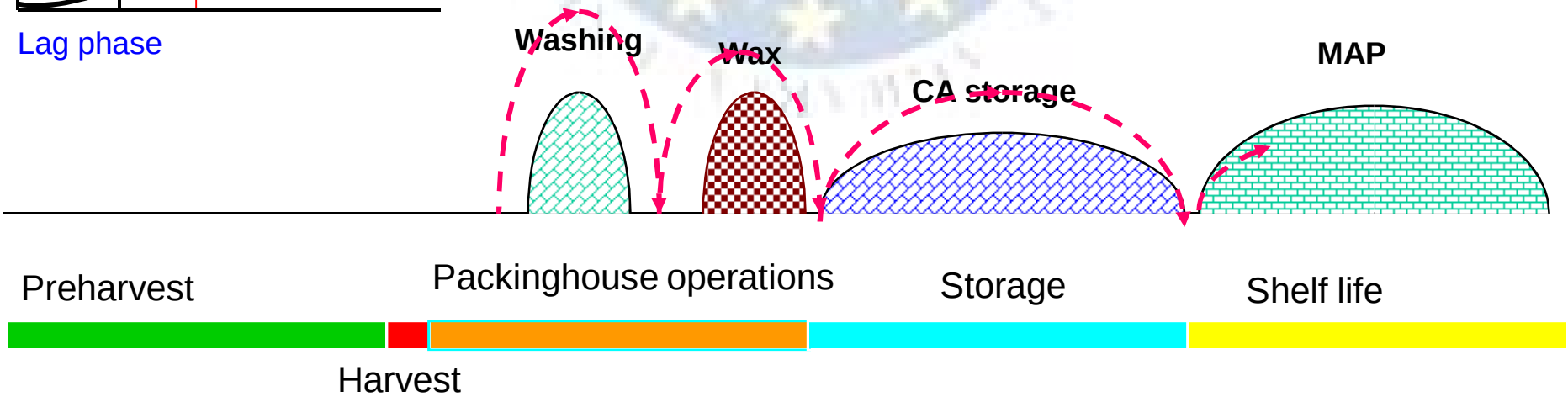
Example: The pathogen present in the packinghouse overcomes ("jump over") all the hurdles but is not able to pass the MAP hurdle

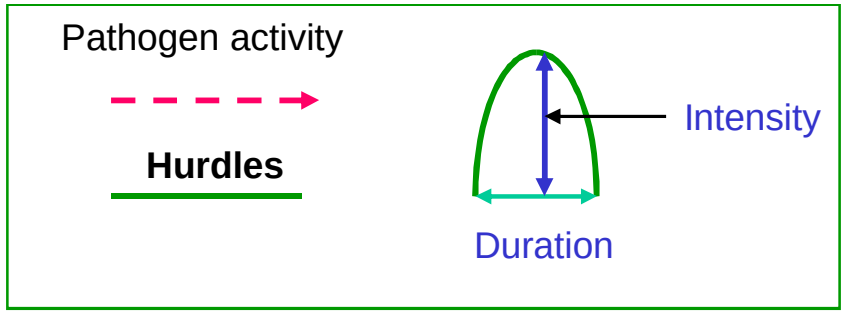


combination of hurdles-the pathogen remains in the lag phase

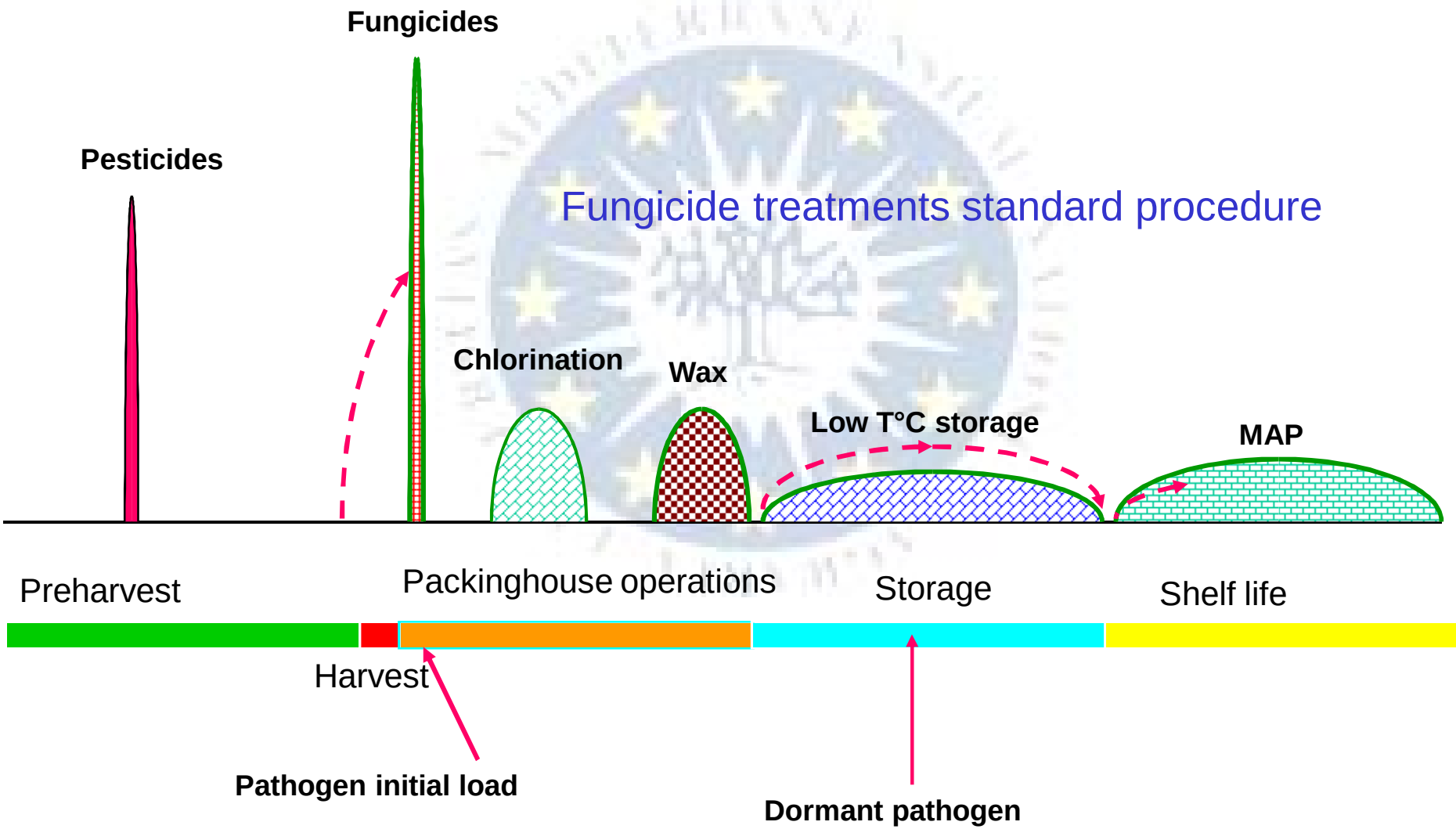
Sigmoid curve of rot development

Lag phase

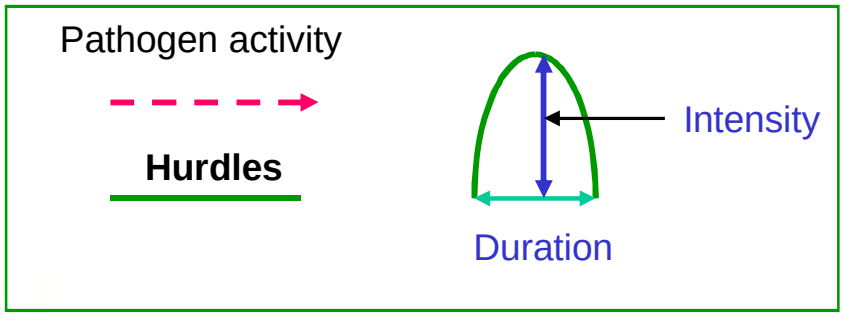




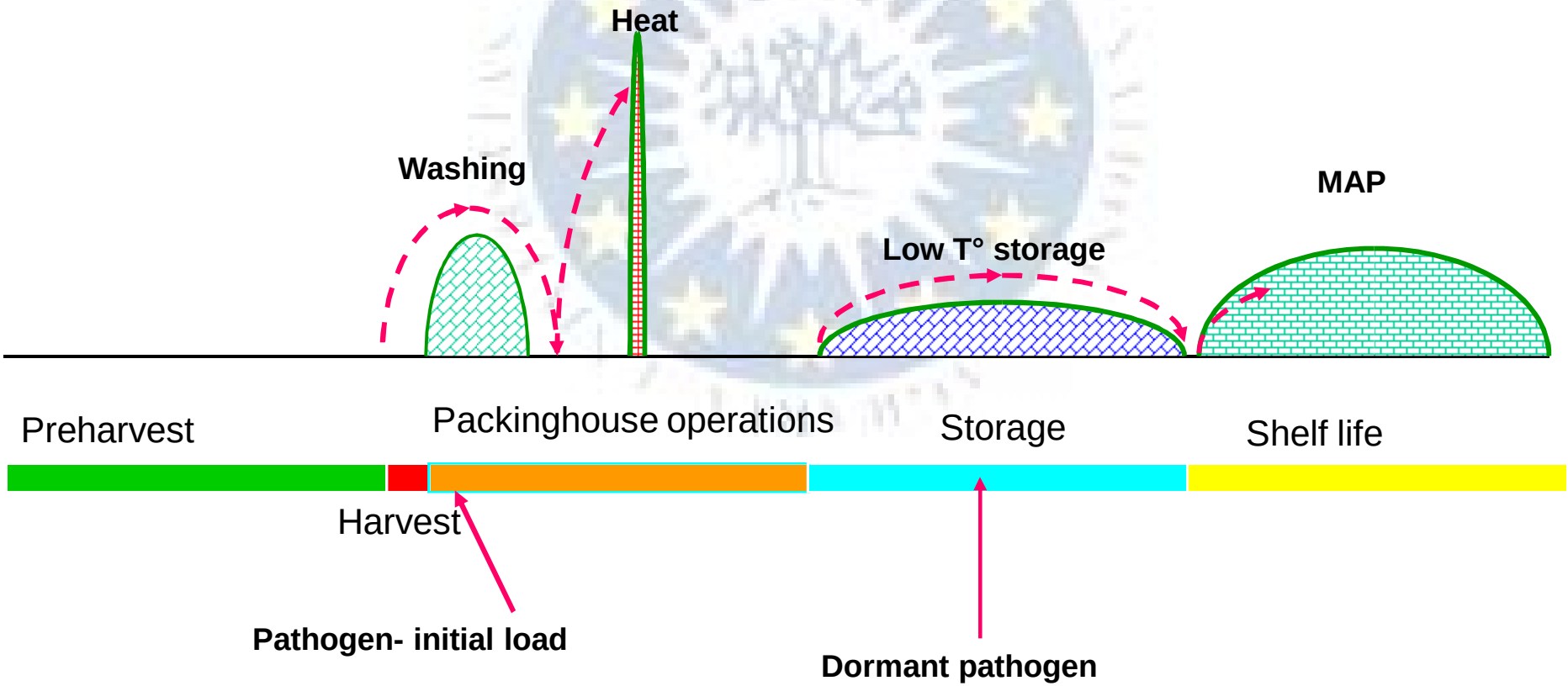
Example: The pathogen present in the packinghouse does not overcome ("jump over") the fungicide treatment. Secondary growth of pathogen will be inhibited by the MAP hurdle

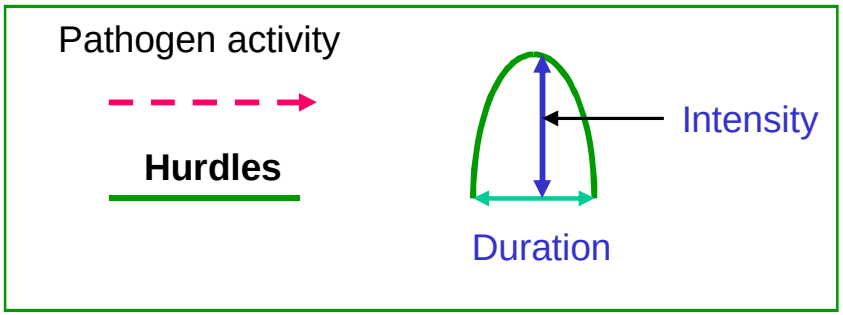


Example: The pathogen present in the packinghouse does not overcome ("jump over")
the heat hurdle. Secondary growth of pathogen will be inhibited by the MAP hurdle



Combination of small alternatives hurdles

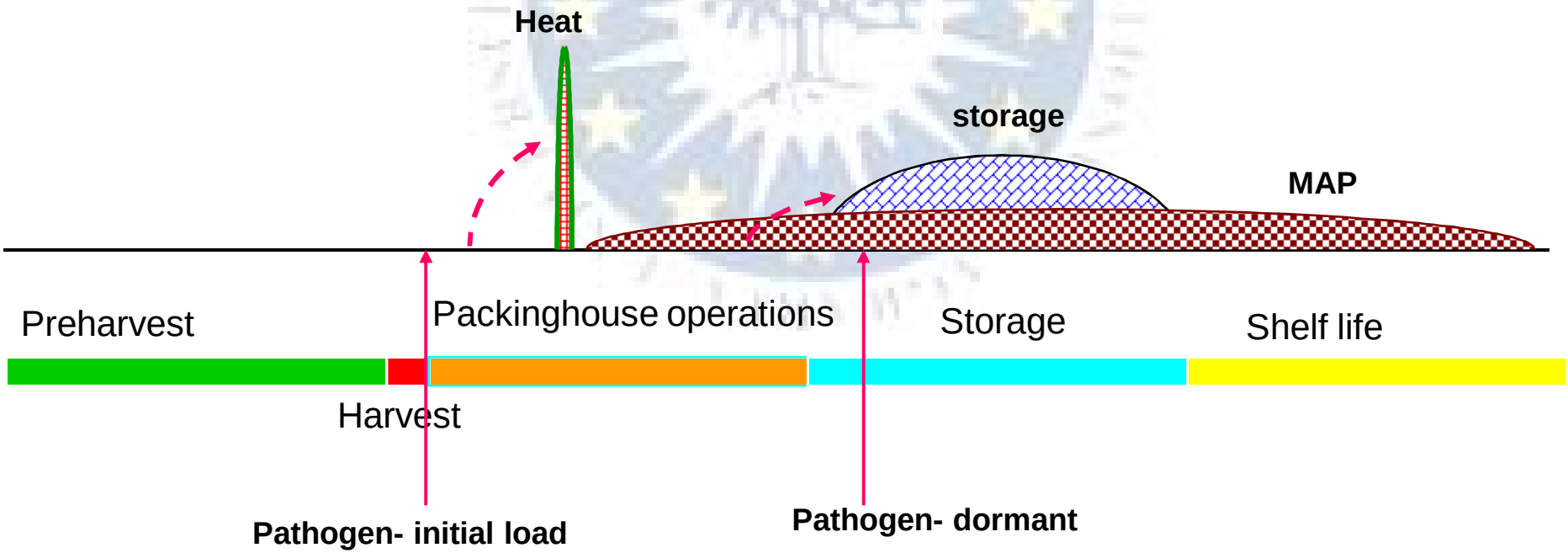




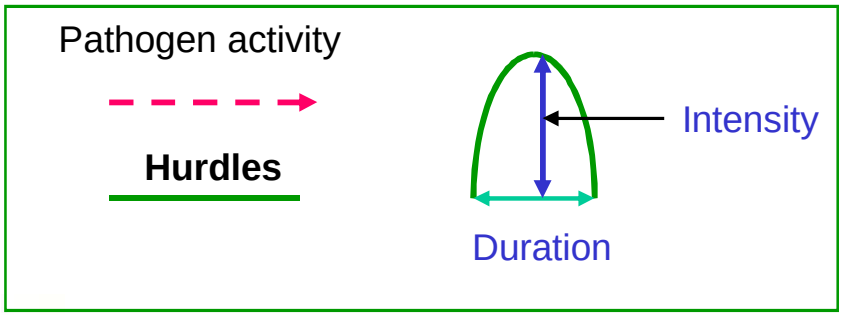
Example: The pathogen present in the packinghouse does not overcomes ("jump over") the heat hurdle and the MAP and storage hurdles

Combination of small alternatives hurdles

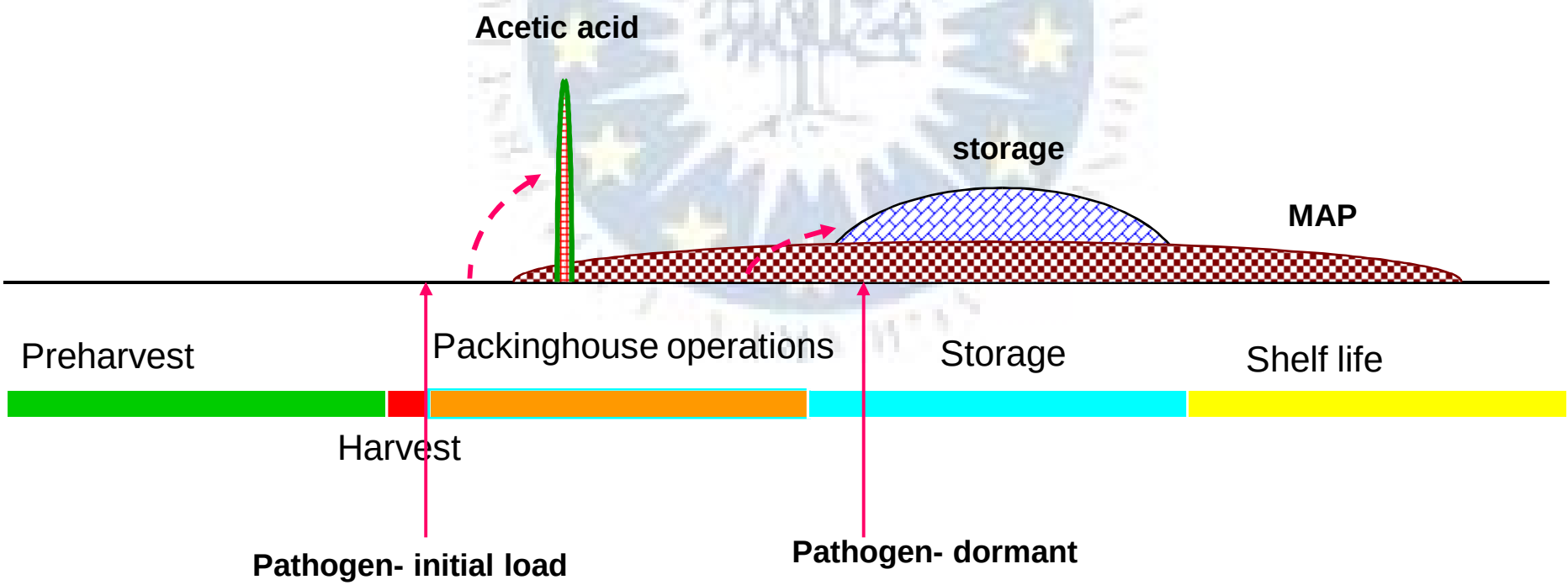
Possible synergistic effects of hurdles



Example: The pathogen present in the packinghouse does not overcomes ("jump over") the Acetic acid hurdle and the MAP and storage hurdles



Possible synergistic effects of hurdles

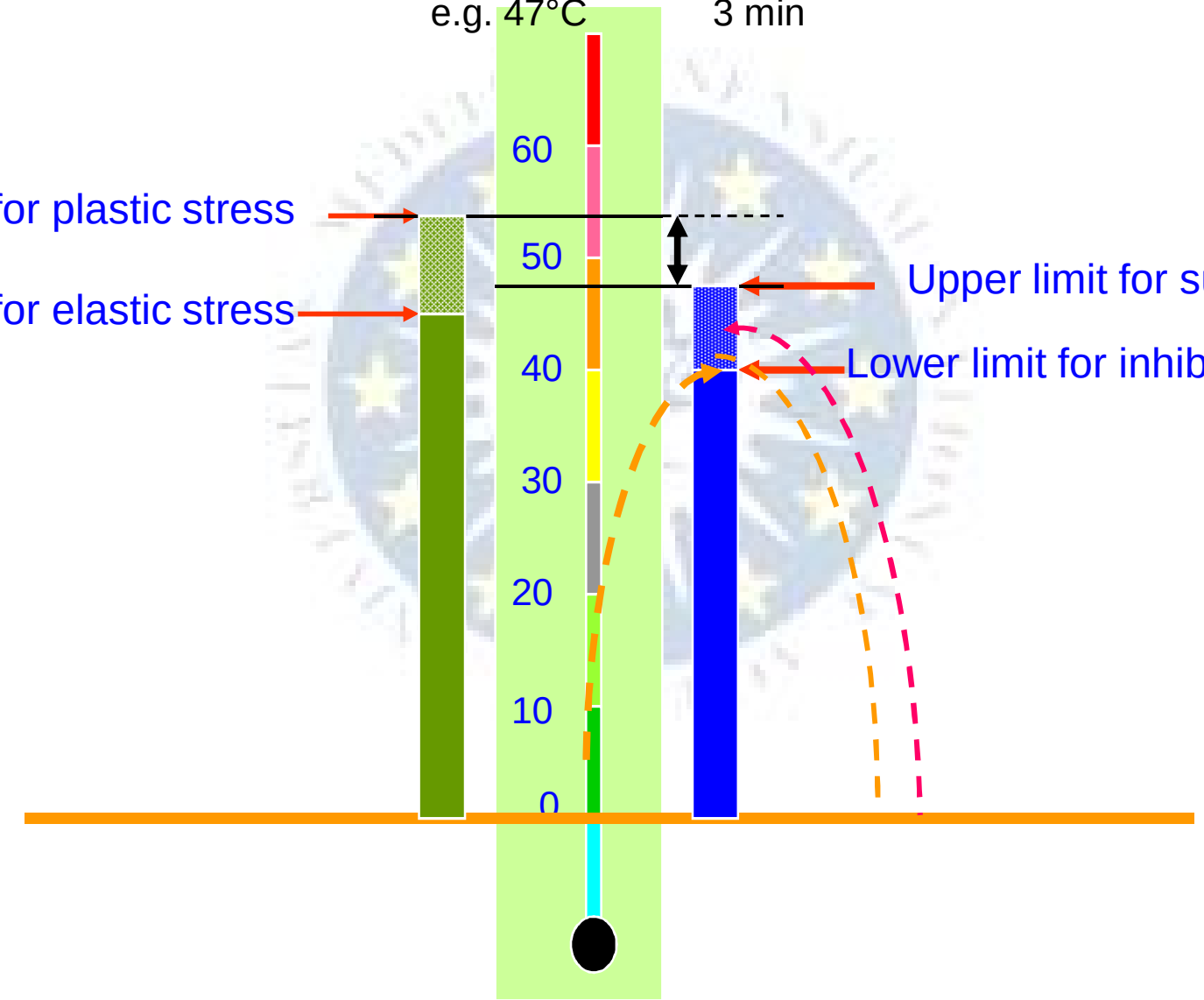


THE HURDLES CONCEPT

Effects on product 's quality

Hurdle Intensity
(Height and exposure)
e.g. 47°C 3 min

Effects on Botrytis



Upper limit for plastic stress

Lower limit for elastic stress

Upper limit for survival

Lower limit for inhibition of growth

°C

40

35

30

25

20

15

10

5

0

High temperature stress

Chilling stress

Low temperature stress

Freezing

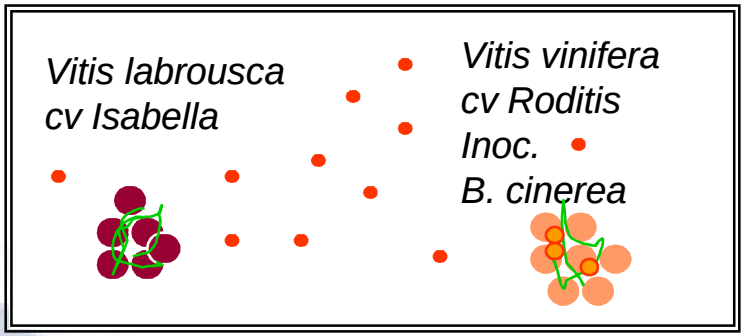
Plants tolerant to chilling

- Apples
- Apricots
- Cherries
- Figs
- Grapes
- Kiwifruit
- Nectarines
- Peaches
- Pears
- Plums
- Raspberries
- Strawberries
- Cabbage
- Brussels sprouts
- Parsley
- Lettuce
- Pea
- Broccoli
- Beet
- Radish
- Celery
- Garlic
- Spinach
- Asparagus
- Been (green, lima)

Chilling sensitive plants

- Endive
- Avocado
- Bananas
- Citrus
- Mango
- Olive
- Papaya
- Pineapple
- Cucumber
- Eggplant
- Okra
- Potato
- Squash
- Sweetpotato
- Tomato
- Watermelon

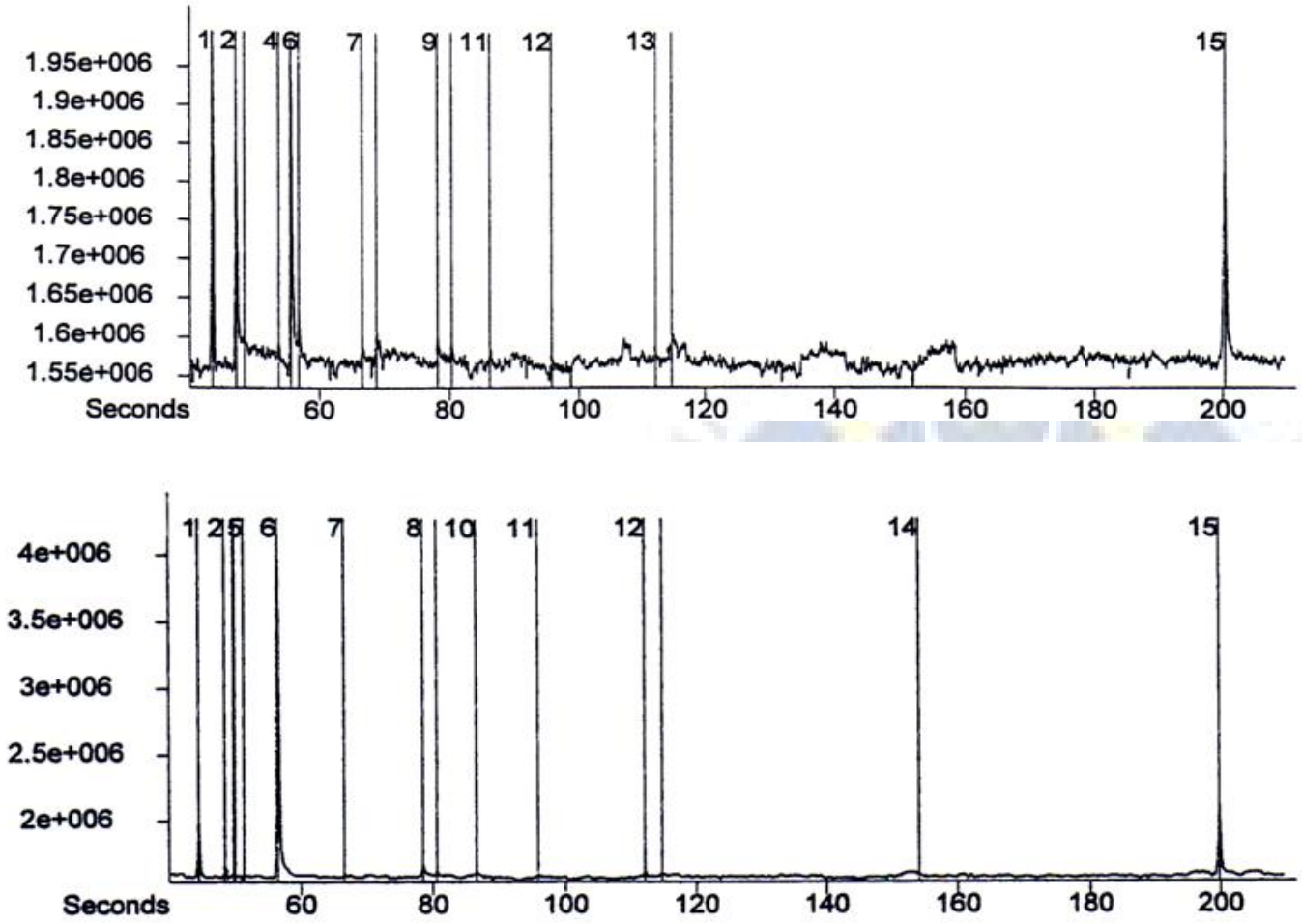
- Volatile substances in the gas phase



In vivo study

Inoculation with
Botrytis cinerea

GS-MS analysis



Compounds unique to *V. labrousca*

- Propanenitrile, 2-hydroxy-2-methyl-propylene glycol
- I-talose, 6-deoxy-3-C-methyl-2-o-methyl-ethyl acetate
- Propanoic acid, ethyl ester
- Hexanoic acid, ethyl ester
- 1-Hexamine
- Butanoic acid, 2-methyl-, hexyl ester

In vitro study of synergistic activity of natural antimicrobials

(nisin, laurocidin) against bacteria (*Salmonella, Listeria* etc).

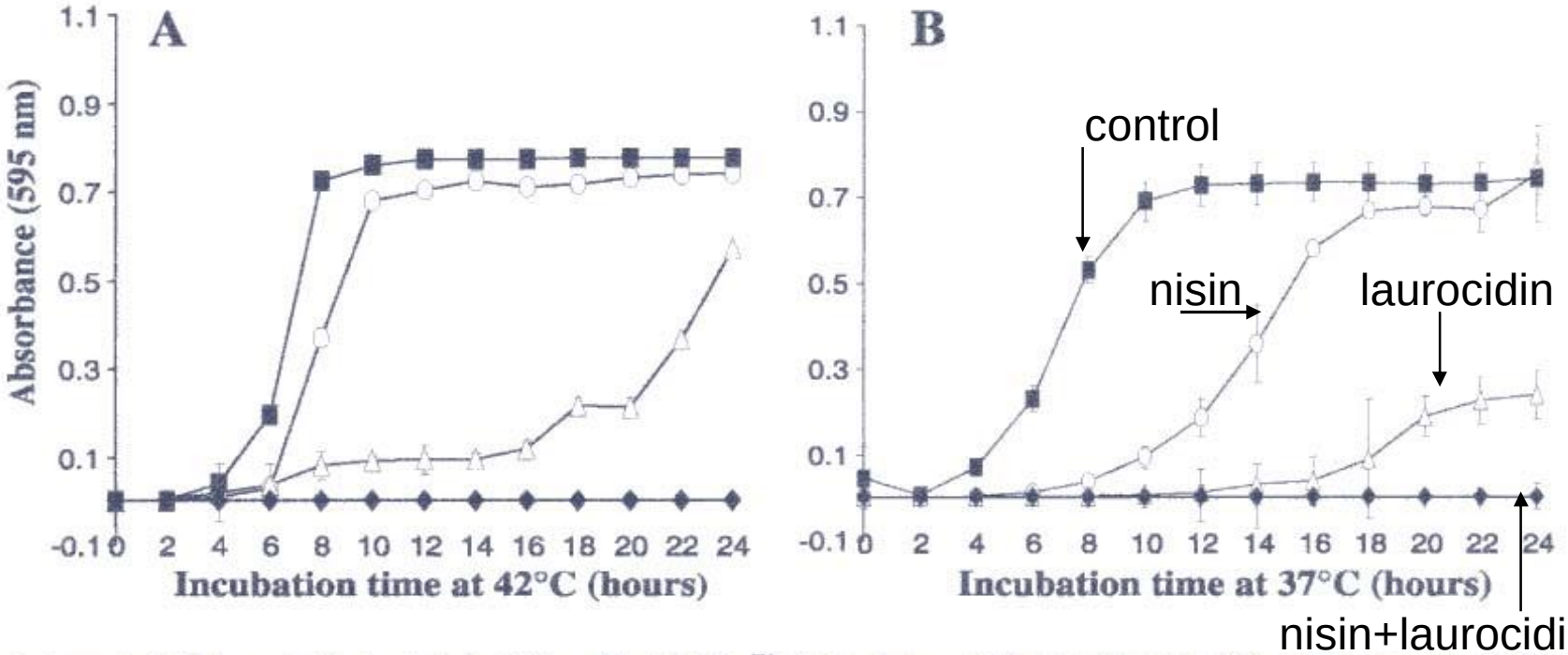


Fig. 3. Untreated control (■), and affect of nisin (○) and lauricidin™ (△), alone and in combination (◆) on the growth of *St. thermophilus* (Panel A) and *S. aureus* (Panel B). Standard error of mean indicated.

Potential safety and quality hurdles

The most important hurdles used in fresh F&V are

low (storage) or high (short term exposure) temperature

CA/MA

MAP

Preservatives

Other hurdles (50 ?) of potential use have been identified

The list is open

Conclusions:

Hurdle technology is used for gentle but effective preservation of foods.

The disturbance of the homeostasis of microorganisms is the key phenomenon of food preservation.

The multitarget approach is more effective than single-targeting and enables the use of hurdles of lower intensity, and thereby has less of an effect on product quality.

The novel and ambitious goal for an optimal food preservation is the multitaget preservation of foods, in which intelligently applied gentle hurdles will have a synergistic effect.

There is an increasing interest to implement the hurdle technology approach in the preservation of fresh fruits and vegetables by selecting mild alternative hurdles which are required for sustainable agricultural production.